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Abstract
The purpose of this document is to present the results of the impact analysis, by assessing the value of the ICT4CART solution and use cases, paying particular attention to the end-user. The aim of the impact assessment as a process is to evaluate the project's actions towards the road transport automation ecosystem.

Legal Disclaimer

Abbreviations and Acronyms

Acronym	Definition
5GAA	5G Automotive Association
ADAS	Advanced Driver-Assistance Systems
API	Application Programming Interface
CBA	Cost Benefit Analysis
CCAM	Cooperative, Connected and Automated Mobility
CEP	Circular Error Probable
C-ITS	Cooperative Intelligent Transport Systems
CO	confidential
CPM	Collective Perception Message
C-V2X	Cellular V2X
EPM	Environment Perception Model
ETSI	European Telecommunications Standards Institute
EU	European Union
GDPR	General Data Protection Regulation
GLOSA	Green Light Optimized Speed Advisory
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
IaaS	Infrastructure as a Service
IAM	Identity and Access Management
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
IoT	Internet of Things
ITS	Intelligent Transport Systems
ITS-S	ITS Station
ISG	Industry Specification Group
KPI	Key Performance Indicator
LTE	Long Term Evolution
MEC	Multi-access Edge Computing Mobile Edge Computing (older term)
NIS	Network and Information Security
OEM	Original Equipment Manufacturer
PoV	Proof-of-Value
PU	public
RSU	Road Side Unit
RTK	Real Tine Kinematic
SAE	Society of Automotive Engineers
SCN	Scenario
SME	Small and Medium-sized Enterprise
TMC	Transportation Management Center
TRL	Technology Readiness Level
ToC	Table of Contents
UC	Use Case
V2X	Vehicle to Everything
VRU	Vulnerable Road User
WG	Work Group
WP	Work Package

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Executive Summary

The aim of the ICT4CART project is to design, implement and test a versatile ICT infrastructure in real-life conditions, which will enable the transition towards higher levels of automation. It focuses on four high-value use cases: Smart Parking & IoT services, dynamic adaptation of vehicle automation level based on infrastructure information, intersection crossing (urban) & lane merging (highway), and cross-border interoperability.

These use cases serve one of the project's main targets, which is to show that the proposed and implemented ICT infrastructure architecture is flexible, adaptable, and can serve the needs of various automated driving use cases (safety, comfort, etc.) with different requirements, across test sites with different capabilities. The ICT4CART use cases can be global or local, can be associated with network slices, can use Edge Clouds/Computing, can use different radio technologies and can be used everywhere (roaming aspect). They also consider mechanisms for cyber-security, authentication, integrity protection and privacy. For this purpose, four test sites are involved in ICT4CART, namely in Austria, in Germany, in Italy and a cross-border site at the Austrian-Italian borders.

The main objective of WP8 is to evaluate the performance of the ICT4CART architecture through the proposed scenarios defined for each test site. This deliverable presents the results of the impact analysis, by assessing the value of the ICT4CART solution and use cases, paying particular attention to the end-user. The aim of the impact assessment as a process is to evaluate the project's actions towards the road transport automation ecosystem. Unfortunately, due to the COVID pandemic, the consortium had to cancel all planned large scale and open to the public demonstration events. As such, only a few participants that were members of the ICT4CART consortium had the chance to participate in the evaluation events and provide their significant but rather limited to what expected feedback.

In Section 1, the purpose of this document is described, as well as the audience it targets. In Section 2, a short validation of the project's outcomes against the initial objectives is presented. Section 3, is dedicated to the project specific impact KPIs and how they were tackled during the project lifetime. Section 4, presents the potential long-term implicit impact of ICT4CART beyond its specific objectives towards different societal and environmental aspects. Section 5, provides a small summary towards the exploitation and extension of ICT4CART results by consortium members, whereas Section 6 presents the analysis of the small-scale questionnaire-based user acceptance. The questionnaire used is also presented. Lastly, Section 7 concludes the report.

1 Introduction

1.1 Purpose of the document

The impact assessment task of ICT4CART WP8 and this report intends to sketch a Proof-of-Value (PoV) based on the outcomes of the test sites operation. The impact assessment first focuses on the assessment of the value of the ICT4CART solution and use cases, paying particular attention to the end-user. Consequently, this report includes the following:

- Analysis of the end-user KPIs achieved in the different automated driving use cases, thanks to the proposed ICT4CART infrastructure.
- Understanding to what extend the results can be extended to other use cases. Investigation if there are additional (or alternative) use cases benefitting from the proposed solutions, based on the practical experience matured throughout the test sites operation.
- Investigation of the user acceptance. This aspect also will be taken into account, though in a limited way. Due to COVID pandemic only a few ICT4CART partner-related users were involved in an anonymous questionnaire.
- Draw conclusions on the potential impact of the technology/solution considering the (a) benefits on the use cases and (b) recapping on the factors potentially hampering its penetration (alternative/competitive solutions, infrastructure constraints, costs, standardisation time, legal issues, etc.)

Thanks to the generalisation of the results to additional use cases, this report also permits the overall evaluation of the role of the infrastructure in enabling the transition towards road transport automation.

1.2 Targeted audience

This deliverable is addressed to any interested reader (i.e., PU dissemination level) who wishes to be informed of the ICT4CART project impact assessment and, in particular, to the readers who want to be informed about the user acceptance of the proposed Use Cases and the project's long term implicit societal and environmental impact.

2 Validation against project objectives

2.1 Objective 1

Identify the functional and technical connectivity requirements posed by the needs of higher levels of automation (SAE L3 & L4) ensuring communication redundancy and increased reliability.

The detailed set of ICT4CART system requirements is identified and described in detail in the corresponding deliverable “D2.3 System Requirements”. Those requirements were generated by taking into consideration the detailed specifications of the Use Cases with the corresponding high-level requirements stemming from there and with reference to the ICT4CART architecture (Figure 1). Specifically, regarding the connectivity requirements to support continuous and seamless communication, for the needs of higher level of automation, a dedicated assessment took place.
Four different requirement categories were identified to cover such needs:

- Seamless and continuous communication;
- Performance and resilience;
- Networks selection;
- Network architecture.

This requirements elicitation process took into account both commercial cellular networks (LTE/5G) and ad-hoc short-range communication networks (ETSI ITS-G5), as well as the need to measure the performance of the proposed flexible network architecture. D2.3 (an ICT4CART CO-access deliverable), summarizes in detail the list of requirements related to the performance of this hybrid communication network which is needed to provide the required level of redundancy, reliability, and availability for higher levels of automated driving.

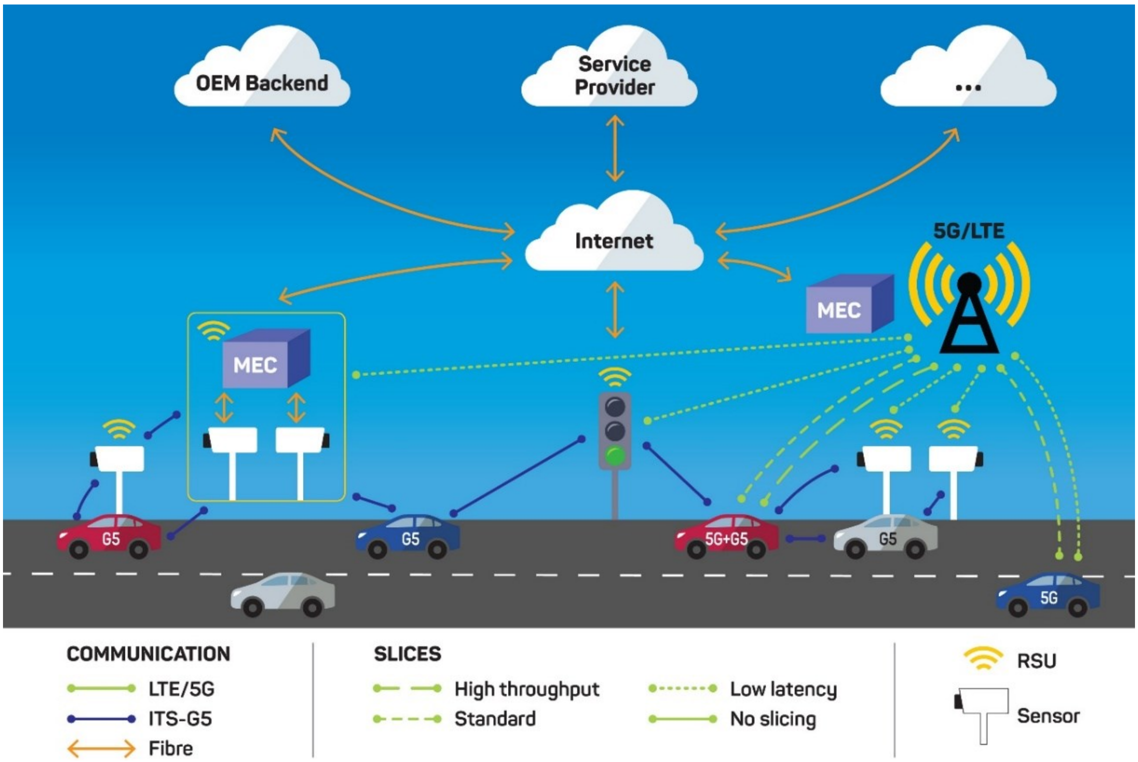

Figure 1: ICT4CART high level Architecture Overview

Following the identification of the functional/technical and the non-functional requirements, the detailed ICT4CART network architecture was implemented. Several tests were conducted on a per use-case basis, in simulation within the labs and also in real environment during the test sites' runs. Measurements regarding latency, reliability, coverage, bandwidth, and granularity were taken and validations against the corresponding KPIs took place (the technical KPIs measured in ICT4CART can be found in the PU-access deliverable "D8.1 Evaluation Methodology" whereas the actual evaluation measurements can be found in the PU-access deliverable "D8.3 Technical Evaluation – Final version").

2.2 Objective 2

Implement and test a standards-based distributed IT environment for data aggregation capable of collecting and managing in an automated and interoperable way all the exchanged data regarding the driver, the vehicle, the vulnerable road users (VRUs) and the infrastructure, leveraging also cloud technology.

The ICT4CART IT environment architectural view, as described in PU-access deliverable "D3.3 IT environment Specification and Architecture", covers functionalities required by connected automated driving, such as data exchange and management aspects, data analytics, semantic interoperability, environment perception models (EPM), and high-precision positioning. In more detail, the following aspects have been considered in the context of the project:

- Common interfaces and services for data exchange through multi-access edge or cloud computing,
- Common or generic analytics platforms and algorithms (e.g., traffic jam analysis, parking and charging station availability prediction, etc.),
- Building environment perception models,
- Common services for precise localisation,
- Semantic interoperability.

The design process of this architectural view started by identifying the commonalities between the various use cases in terms of the data flows. This further allowed the identification of the common architectural components and data exchange standards to comply with across the test sites.

D3.3 further elaborates on the IT Environment Architecture that has been implemented in the context of WP5. The functional viewpoint of the overall ICT4CART ICT architecture is illustrated below in Figure 2.

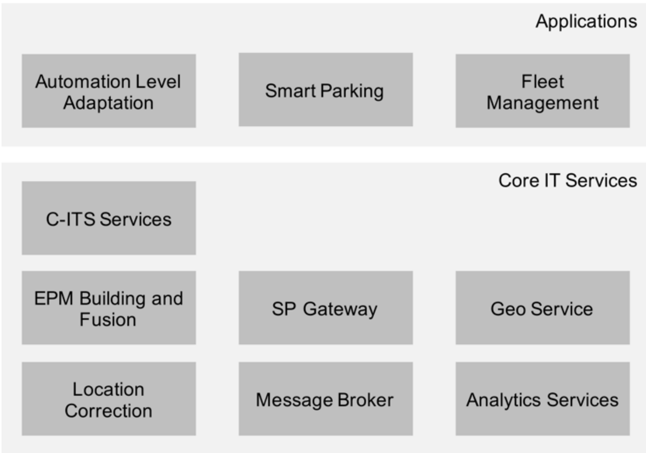

Figure 2: ICT4CART Functional Architecture

A high-level component viewpoint of the ICT4CART IT environment architectural view is provided below in Figure 3. In this figure, the vehicle is not considered as part of the IT environment, but rather considered as a client.

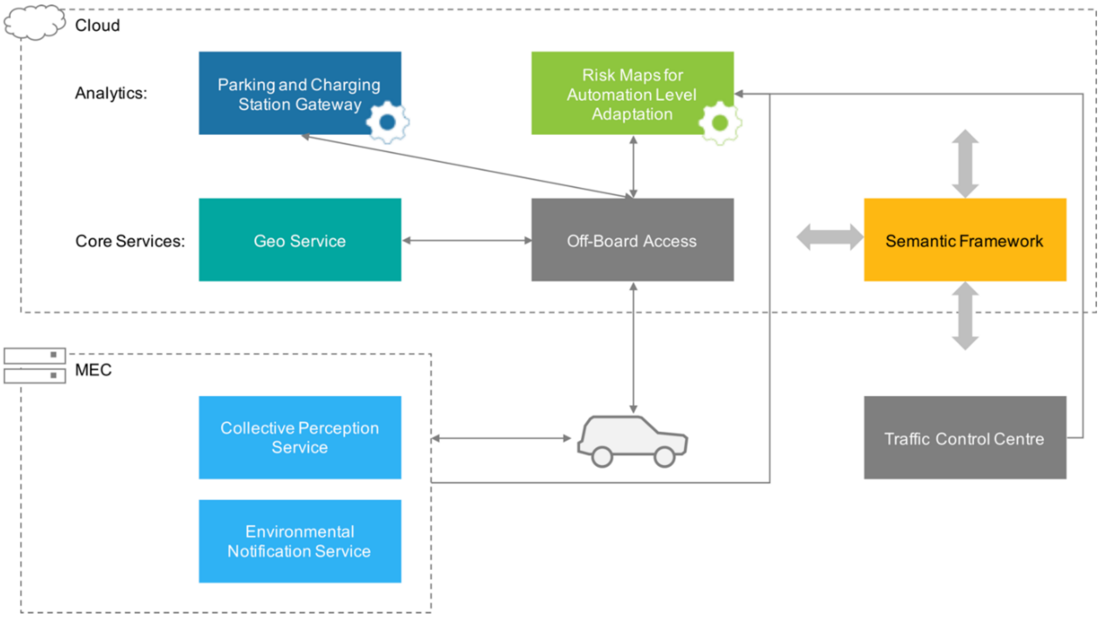

Figure 3: ICT4CART IT Environment Architecture – Component Viewpoint

Following the implementation, the distributed IT environment has been tested as part of the overall solution in the Austrian, German, Italian and Cross-Border test sites running scenarios implemented under each use case.

2.3 Objective 3

Implement cyber-security and data protection and privacy mechanisms aligned with the EU policy objectives.

ICT4CART consortium made a thorough analysis of the certificate policy for deployment and operation of European C-ITS, the security, policy & governance framework for deployment and operation and several standards, including ETSI, C2C-CC, ISO/SAE 21434, EU Directive 2016/1148 (NIS directive), the GDPR and the outcomes of SeVeCom[1] and PRESERVE[2] projects. The European standards and regulations analysed are being followed and respected in the automotive sector.

Following the initial analysis, several mechanisms were developed to implement cyber-security, data protection and privacy in the context of supervision and data privacy services, within the project's overall solution. PU-access deliverable "D3.4 Cyber-Security and Data Privacy Specifications and Architecture", describes in detail the Cyber-Security Supervision Architecture as proposed by the project experts. The same deliverable provides insights on the Identity and Access Management (IAM) Service and Data Privacy Architecture. The deliverable describes services' role, presents the interacting actors, illustrates the functional architecture, details the functional blocks, and depicts the support capabilities and the external interfaces. The requirements relevant to cyber-security and data privacy have effectively been covered and validated against the architecture proposed.

In a nutshell, the cyber-security supervision service analyses cyber-security events collected from vehicles, RSUs, MEC servers, and cloud services. It assesses vulnerability against known flaws and exploits them, complemented with threat knowledge. Major outputs of the analysis are cyber-security incidents that require to be considered by road operators, cities, car makers, OEMs and service providers. Periodic cyber-security activity and situation reports extract the big picture of the cyber-

[1] Panagiotis Papadimitratos, Levente Buttyán, Tamás Holczer, Elmar Schoch, Julien Freudiger, Maxim Raya, Zhendong Ma, Frank Kargl, Antonio Kung, Jean-Pierre Hubaux: Secure vehicular communication systems: design and architecture. IEEE Communications Magazine 46(11): 100-109 (2008).

[2] REparing SEcuRe VEhicle-to-X Communication Systems. Deliverable 1.3 V2X Security Architecture v2.

security health of a vehicle fleet, road infrastructure and parking management services for instance. The role of the IAM service is to provide authentication and authorization functionalities to ITS-S and users. The mechanisms used for ITS-S also allow ensuring privacy and confidentiality.

2.4 Objective 4

Improve localisation by combining information from different sources (European GNSS, on board sensors, other vehicles, infrastructure, etc.) and adapt existing tools and algorithms for data fusion.

The improved localization mechanisms in the context of the project are presented in CO-access deliverable "D5.9 Implementation of High Precision Positioning – Final Version". The deliverable summarizes the High Precision Positioning Architecture and introduces the precise localization service which uses a combination of different sources and is based on the Real-Time Kinematic (RTK) technique, that enhances the precision of the Global Navigation Satellite System (GNSS) by using carrier phase measurements and correction data of RTK reference stations, thus achieving an accuracy of up to 1-2cm + 1ppm (CEP) in case of optimal reception conditions at the client side. A MEC server also makes use of correction data provided either by an external service provider (e.g., SAPOS) or by dedicated RTK reference stations co-located with the LTE/5G mobile radio network.
The service was tested and validated in real use cases. As an overall conclusion, measurements were made and an accuracy of up to two centimetres has been achieved. In the German and the Italian test site, the evaluation of mass market products such as the u-blox F9-series has shown as result sufficient accuracy. In the German test site, the correction signal is available via the MEC server. As the correction information is not time critical compared to other transmitted messages, the use of a MEC server is not necessary and a cloud server could be used instead.

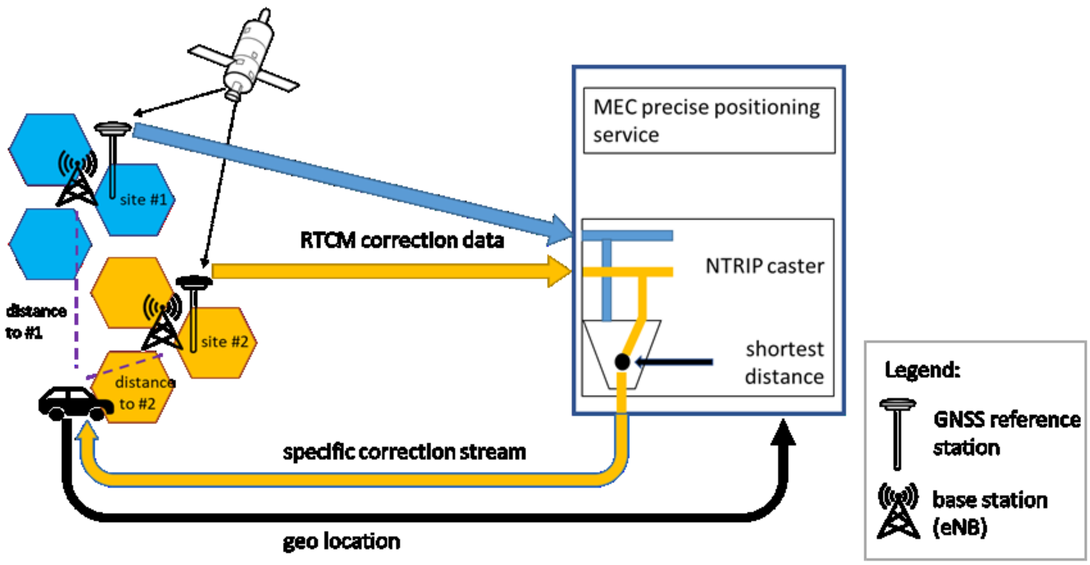

Figure 4: German Test Site Approach for Precise Localization

The processing time and wired transfer of the correction data to a cloud server is negligible in contrast to delays e.g., from being out-of-coverage leading to longer service interruptions.

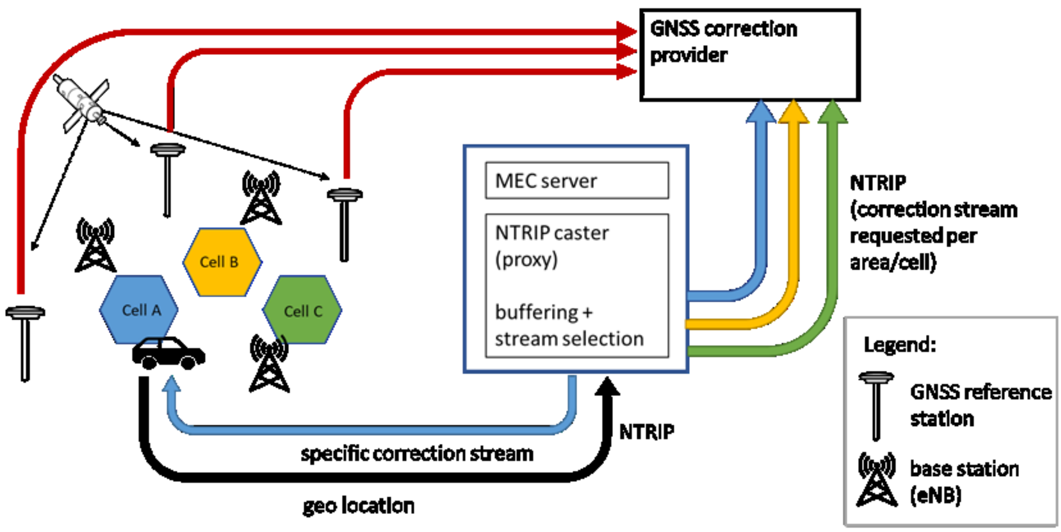

Figure 5: Austrian and Italian Test Site Approach for Precise Localisation

In the Austrian/cross border test site, the focus of the test was on the availability of the data correction stream in difficult terrains (mountainous area). It was shown that the system is working in most of the cases, but only the combination of GNSS and other localisation technologies lead to a sufficient precise positioning service.

2.5 Objective 5

Validate and demonstrate the ICT Infrastructure architecture through the project use cases and test sites.

The solutions proposed by ICT4CART were integrated and tested in real-life conditions at the project test sites through the specific use cases and the corresponding traffic situations called "scenarios", which have been defined in PU-access deliverable "D2.1 Specification of Use Cases". PU-access deliverable "D7.2 Adaptation of the reference architecture at the test sites" outlines the concrete ICT architectures that were implemented at the different test sites.
The ICT4CART reference architecture was adapted according to the needs of each test site. Each test site architecture takes into account the specifics and capabilities of the corresponding test site and is tailored to the needs and requirements of the respective use cases and scenarios that were demonstrated. The common reference architecture of ICT4CART, however, guarantees the interoperability of the developed traffic and communication system innovations for all test sites. In most cases, some modules of the reference architecture were not necessary and therefore were not set into function.
Different scenarios of the four high-level use-cases were experimented in the Italian test site in highway and urban areas. In detail, in the highway areas of the Italian test site the following scenarios were implemented:

- SCN2.2/SCN2.3: Adaptation based on Infrastructure information concerning pedestrian, presence of queue and wrong-way driving warning.
- SCN2.2: Information at motorway toll station, with infrastructure information concerning queue and wrong-way warning.
- SCN3.3: Virtual mirror for lane merging.
- Dynamic adaptation of vehicle automation level based on infrastructure information, such as accident and speed limit.

In the urban area the following scenarios were implemented:
- SCN2.3: Adaptation based on Infrastructure information concerning pedestrians.
- SCN1.2: Urban parking.
- SCN3.2: GLOSA at signalized urban intersection.
- SCN3.1b: Virtual mirror for non-signalized intersection crossing.

In the German test site, the following scenarios were implemented:
- SCN 1.1 - Smart Parking and IoT Services in City of Ulm.
- SCN 3.1a - Virtual mirror to "see" surrounding traffic in urban environment in City of Ulm.
- SCN 3.4 - Precise positioning in urban and highway location.

In the Austrian test site, the following scenario was implemented:
- SCN2.1 - Dynamic clearance, adaptation and handover of vehicle automation level at special conditions in Graz.

The same scenario was also implemented in the Cross-border site between the Italian-Austrian borders (Brenner passage).

The scenarios implemented and tested in the ICT4CART test sites represent four high-value use-cases of interest for the project:
- UC1: dynamic adaptation of vehicle automation level based on infrastructure information.
- UC2: virtual mirror for intersection crossing (urban) and lane merging (highway).
- UC3: smart parking & IoT services.
- UC4: cross-border interoperability.

2.6 Objective 6

New business models and market services for the innovative use of cross-sector data, including the creation of services linked to the ICT infrastructure for automated driving.

At the very early stages of the project, the consortium carried out several Cost Benefit Analyses. Those analyses were complemented by Market Sustainability assessments, to determine and provide an estimate around the costs of ICT4CART in order to support the services and accommodate any potential customers willing to pay for those services, thus creating revenue streams. A value proposition was developed for a total of 24 CAV information services to identify and validate how the services are addressing customer needs. The 24 services captured address the needs of six market groups:

- **Automated driving**: connectivity to support the automated decision making of road vehicles.
- **Informed journeys**: connectivity to improve driving decisions, regardless of how automated the vehicle is.
- **Intelligent management**: connectivity to improve awareness of what is happening on a road network.
- **Coordination of vehicles**: connectivity to instruct automated vehicles in specific scenarios and coordinate their driving.
- **Connected travellers**: connectivity to connect vehicle passengers and improve their experience.
- **Underpinning services**: connectivity services with commercial potential that enable a safe and effective communication network.

As identifying the value and market is only one portion of a complete business model the 24 CAV information services were further refined into business model blueprints that can be used as a guide for refined business model development. This exercise is very helpful for the estimation of each business model's sustainability. The business models are not quite as innovative as anticipated at the project initiation as the industries and technology have made significant progress over the project's execution period. This rapid industry progression helps validate the business potential of the ICT4CART use cases and scenarios. The following table shows which services were grouped to create business model blueprints laying the foundation for sustainable businesses.

Innovative Business Model	CAV Services Bundled
Government Authority **- includes CAV Services that** could be expected to be provided or even be enforced by a government or public authority	• Traffic Management Information • Traffic Conditions • Basic Vehicle Information • Incident Management • Smart City Management
Core Safety - **CAV Services that** support safety features **anticipated to be required in all vehicles over time**	• Smart System Information • Sensed Road User Information • Directly Communicated Road User Information
Digital Environment - **CAV Services** that **enhance the real time detail of the temporal and spatial digital world beyond the immediate vicinity**	• Environmental Information • Infrastructure and environment information • Predictive Quality of Connectivity
Consumer Services - **encompass the content and platforms for passengers to be entertained and productive while travelling**	• Event Information • Availability of supporting service infrastructure • Enhanced journey information
Supplementary Services - **enhance the core** (automated) **driving function to enable fleet level coordination operations**	• Platoon Coordination • Coordinated Corridors • Space Management Services • Fleet Optimisation • User Specific journey information
Transferrable Services - **are** already **available in other industries but have** an **application in CAV's**	• Secure communication services • Over the air software updates (OTA) • Cybercrime preventions services • Internet enabled consumer services • Other road and fleet management services

In general, all the business models are utilising the ICT4CART solution and have broad market application due to the range of services that they can deliver to CAV's. While some have existed in various forms for many years, the target markets are still in their infancy. The opportunity only increases as the market penetration of automotive connectivity and autonomy progresses.

Further detailed reports on the market and cost analysis can be found in PU-access deliverables "D2.2 Market Analysis" and "D8.5 Cost Analysis". PU-access deliverable "D9.10 Business models" offers an extensive report on the innovative business models based on the ICT4CART use cases and test sites, providing details on the aforementioned cases and creating a guide for business strategy.

2.7 Objective 7

Promote the project developments to standardisation bodies and policy makers especially in relation with actions requiring public authorities' intervention.

Several communication, dissemination & liaison activities were carried out by the whole consortium throughout the entire lifecycle of the project. More specifically, regarding the promotion to standardisation bodies and policy makers:

- The demonstration of the parking availability notification service, wrong-way driving and approaching to the toll barrier use cases of the ICT4CART have been introduced in the ETSI TR 102 638 release 2 which is in drafting phase.
- Interaction with Rapporteur of ETSI ITS WG1 Work Item on Cooperative Perception Services (ETSI TS 103 324) to introduce proposal of UULM for CPM extension took place.
- Interaction with ETSI MEC ISG is scheduled to take place when the implementation of MEC platform and related application will be completed.

A large number of workshops aiming to raise public authorities' awareness and interventions, including discussions around ICT4CART results and outcomes, took place throughout project lifespan. We list some of them below:

- EUCAD 2018 Conference;
- ITS World Congress 2018;
- ARCADE 2nd Stakeholder workshop;
- All energy exhibition & conference;
- ITS Europe Conference 2019;
- Automated Vehicles Symposium 2019;
- EUCAR Safe & Integrated Mobility Programme Board Meeting 2019;
- ITS World Congress 2019;
- TRB Annual Meeting 2020;
- IEEE International Mediterranean Conference on Communications and Networking 2021;
- ICTR 2021;
- 2021 IEEE Vehicular Networking Conference (including one of the ICT4CART Final Events);
- ITS World Congress 2021 (including one of the ICT4CART Final Events);
- Innovation congress Ulm;
- Smart City Week in Trento;
- EUCAD 2021
- ITS Hellas 2021
- 2 webinar discussions with ICT4CART AB (M18, M35)
- ICT4CART stakeholder Forum Campaign discussion in M20.
- And many more!

In terms of liaison and networking activities, ICT4CART networked with ten (10) R&D projects, seven (7) organisations/platforms/associations and conducted at least 20 various liaison related activities.

To ensure an effective networking and knowledge exchange, an Advisory Board (AB), consisting of ten (10) members, has been formed by external professionals, involving different groups (automotive, ICT, telecommunication, academia) and utilising the existing networks in the consortium. The project partners also formed a dedicated Stakeholder Forum, including experts and relevant stakeholders with over 230 members be kept informed on a regular basis about ICT4CART major achievements and work progress through the ICT4CART e-newsletter, the social media activities, press articles, physical/remote meetings/workshops etc.

The KPIs set for the project's website https://www.ict4cart.eu/ were meet. More than 100 unique visitors per month have been recorded between its launch (M6) and February 2022 (M42). Furthermore, ICT4CART's LinkedIn group reached 155 members (target was 150), with more than 50 started discussions. In addition, project video and trailer were created for the second social media campaign, where the project's results were highlighted (the hashtag “#ICT4CARTresults” was created). The video can be seen at the following link: https://www.youtube.com/watch?v=NevemXEPfbo

Unfortunately, due to the COVID-19 pandemic, several communication and dissemination activities including key conferences and international events were cancelled. The consortium came up with alternatives, such as webinars, on-line interviews and newsletter, in order to keep communicating and disseminating the key findings and results of ICT4CART.

A more detailed report on the achievements of the project's communication, dissemination and liaison activities can be found on the PU-access deliverable "D9.7 Final report on communication, dissemination & liaison".

3 Project Specific Impact KPIs analysis

Impact is one of the most important aspects for the evaluation of the project's achievements while also determining its value. In this context several impact related KPIs have been foreseen. In this section those KPIs are being discussed and ways towards achieving them are briefly presented.

KPI1: At least 3 EC platforms/fora/initiatives (e.g. Automotive-Telecom Alliance, C-ITS platform) will accept/be informed of ICT4CART infrastructure architecture. At least 2 living labs/competence centres will adopt ICT4CART architecture.

In the context of this KPI, the proposed ICT infrastructure architecture of ICT4CART adapted and deployed in the different test sites was validated and demonstrated in real-life conditions. The technical feasibility, flexibility, adaptability, innovation potential and pragmatic impact of this ICT infrastructure architecture was proved within these demonstrations. This action was performed to provide tangible evidence regarding usefulness and increased the interest of key stakeholders (OEMs, Telecom, Road operators, service providers, etc.) to invest. Several liaison activities, important to ensure knowledge exchange between key actors and the adoption of the proposed solutions, have been performed throughout the project's duration and several interactions with standardization bodies took place. PU-access deliverable "D9.7 Final report on communication, dissemination & liaison" provides the final report on those activities. More specifically, Sections 6 and 7 are dedicated to "Liaison and Networking Activities" and "Standardization Activities" respectively. The ICT4CART infrastructure architecture, aims to serve as a starting point, to be further developed and extended so that it can be adopted from the test sites where it was demonstrated. Despite the circumstances with regards to the COIVD-19 pandemic and the restricted level of activities, this KPI can still be considered as fulfilled.

KPI2: A CBA analysis will be performed for all the ICT4CART use cases. At least 3 different communication technologies will be considered and benchmarked.

In the context of this KPI, Cost Benefit Analyses were carried out in the early steps of the project regarding ICT4CART use cases. These CBAs were combined with market sustainability analyses and were supported by analyses of market needs. PU-access deliverables "D8.5 Cost Analysis" and "D9.10 Business models" provide further details around these topics.

In addition, benchmarking between different communication technologies (ITS G5, LTE/5G), platforms and tools considering parameters such as performances, reliability and costs were conducted. Further details regarding the communication technologies utilized by the project and their respective performance can be found on the PU-access deliverables "D3.3 IT Environment Specification and Architecture" which provides the description of the proposed solution and on deliverables D7.3 "Italian Test Site" , D7.4 "German Test Site", D7.5 "Austrian Test Site" and D7.6 "Cross-border Test Site" that describe the testing activities conducted per test site together with the benchmarking of the aforementioned technologies (the above deliverables are CO). Based on the previous reports, this KPI is considered as fulfilled.

KPI3: Active participation of consortium partners in at least 2 relevant WGs in standardisation bodies. Participation in minimum 3 events related to standardisation throughout the project.

The target of ICT4CART behind this certain KPI is to identify the gaps related to automated driving and ICT architectures and propose updates addressing mainly interoperability and cyber-security aspects. The consortium targeted several standardisation activities in the field to manage these needs, raising awareness around the innovative proposed solution, as also mentioned in Section 2.7. Further details on how this KPI is fulfilled and on the activities towards managing the goals are reported on the PU-access deliverable “D9.7 Final report on communication, dissemination & liaison”.

KPI4: The TRL for the real time control systems associated with the project use cases is expected to reach 6.

The project primarily focused on the creation of the core elements such as hybrid connectivity, data aggregation, cyber-security and data privacy combined with the appropriate ICT infrastructure to enable timely control of the connected vehicles. On this direction, a set of scalable and sustainable control strategies for real time control of a multitude of vehicles have been implemented. Those aspects are expected to be further utilised for efficient traffic management and support real time decision making. As mentioned on Section 2.5, ICT4CART managed to develop, validate, and demonstrate the proposed solutions with the appropriate level of ICT Infrastructure architecture through the execution of several test cases, in real life conditions, on four test sites. In principle, TRL 6 is reached when a “System’s Adequacy is Validated in Simulated Environment”. The test cases, test results and relative outcomes, are described in detail on deliverables D7.3 “Italian Test Site”, D7.4 “German Test Site”, D7.5 “Austrian Test Site” and D7.6 “Cross-border Test Site”. Therefore, this KPI is successfully fulfilled.

KPI5: Specification of a real-time data basis (data categories and their properties, in particular spatio-temporal densities) sufficient for generating speed and lane recommendations for automated vehicles. IT system and data aggregation successfully employed in all ICT4CART use cases and test sites. The achieved localisation accuracy (exploiting all available sources) is aligned with ICT4CART specs. Implementation and promotion to standardisation bodies of the Environment Perception Models.

ICT4CART targeted implementing an interoperable IT environment includes several tools and mechanisms to avoid channel overloading and algorithms for fusion of V2X data with on-board sensors, adapted and re-used from previous partners’ works.

Specific system requirements were developed in the context of WP2 and can be found within CO-access deliverable “D2.3 System Requirements”. PU-access deliverable “D3.3 IT Environment Specification and Architecture” also provides further details in specifying the IT environment architecture, including data exchange flows and interfaces, management, and analytics, semantic interoperability, and high precision positioning. These implementations, together with complementary related project activities were promoted in combination with standardisation towards the market as part of the communication, dissemination, liaison & standardisation activities carried out in course of the project.

The level of the achieved localisation accuracy aligned with ICT4CART specifications is described in detail in the corresponding test site reports and on Section 6 of the present deliverable as part of the user experience feedback received from the execution of the test cases. This KPI can be therefore considered as fulfilled.

KPI6: Provide an IT environment which will be the basis for a marketplace able to integrate additional services from external developers through standardised and open APIs respecting digital rights management. Provide tools to facilitate data exchange and ease data aggregation by 3rd party service providers.

ICT4CART started with a market analysis early in the project to support the project developments. The consortium focused on the implementation of IT services and tools needed for connected automation across the multitude of communication networks, through the implementation of:

- Interoperable common data exchange and management services.
- Data analytics tools and services required by connected automated vehicles.
- High precision positioning services as required by the automated driving use cases.
- Environment perception models based on the data exchanged between vehicles, and between vehicles and the infrastructure.
- High Precision Positioning based on Real Time Kinematic (RTK) embedded in the Cellular Radio Network providing improved performance and reliability.

With appropriate cloud infrastructures and technologies, the above objectives can contribute to enabling the creation of a marketplace where the implemented data and IT services can be widely deployed.

CO deliverable "D5.6 Implementation of the IT Environment and Data Exchange Services" provides a detailed report on the implementation of the IT environment and data exchange services including user documentation. CO deliverable "D5.7 Implementation of the Semantic Interoperability Services and Ontologies" provides a detailed report on the implementation of the semantic framework and ontologies and how they should be used to facilitate semantic interoperability, including user documentation. CO deliverable "D5.8 Implementation of Data Analytics Framework and Services" presents the implementation of data analytics, the framework used, the services and tools, and how they are and can be used. CO deliverable "D5.9 Implementation of High Precision Positioning" summarizes on the implementation of high precision positioning. And finally, CO deliverable "D5.10 Implementation of Environment Perception Models" serves as a final report on the implementation of environment perception models. Taking into consideration the reporting, this KPI is successfully fulfilled.

4 Impacts beyond project

In this section we shortly present the marker related benefits and the business opportunities as well as the implicit and explicit societal benefits that of the ICT4CART project that span beyond the lifetime of the action.

4.1 Market related benefits and business opportunities

Generally, the adoption of ITS/CCAM systems and services will have a high economic impact according to different complementary reports due to the increased importance of the automotive sector in the EU economy and the number of connected vehicles that is expected to grow in the coming years. McKinsey[3] predicts that the European revenues in the automotive sector that are based on consumer spending will reach EUR 1,400 billion in 2030 (almost the double of the value in 2014). According to another report from 5GAA the net benefits of adopting C-V2X systems will be in the range of EUR 20 to EUR 43 billion for Europe where at the same time it will create 190,000 to 200,000 direct and indirect jobs by 2030. The number of connected vehicles using cellular networks was expected to be 180 million in 2020[4] as car industry stakeholders announced their plans and collaborations with 5G Operators[5]. Another indication of the importance of the ITS/CCAM for the European economy is that according to a recent report[6] published by the European Patent Office the number of patents for self-driving vehicles is growing with a rate twenty times faster than other technologies. ICT4CART aimed to increase the uptake of ITS/CCAM related systems and services. ICT4CART's indirect impact on the European economy was/is to contribute to the acceleration of the deployments of ITS/CCAM in Europe, by examining a set of high demanding UCs and proposing a flexible network architecture. Specifically based in ICT4CART's evaluation results (the corresponding technical evaluation deliverable D8.3 is also publicly available through ICT4CART web page):

- Automotive industry can improve their vehicle (automated or only connected) capabilities and adapt their products to the future urban and highway mobility and traffic management needs. New data generation and sharing strategies can be developed and vehicles can include new mobility functionalities, such as reacting to cooperative manoeuvres or the presence of emergency vehicles and VRUs. These new implementations will further increase road safety and traffic efficiency; at the same time, they will reduce the environmental impact of vehicles.
- The ICT4CART UC-related service providers will extend their portfolio including new ways of treating data from different sources and making them easily available to others by providing information through e.g., C-ITS services to vehicles and other new interfaces for an easier interoperability and better coordination between actors.
- Road operators and TMC operators can significantly benefit from the wealth of information provided by the connected vehicles allowing them to use new strategies and tactics in traffic management. The possibility of interacting with the vehicles using hybrid connectivity options allows the road operator to manage demand by establishing guidelines for the behaviour of the vehicles.
- Telecom Industry can benefit from the more widespread use of its services since they will be the enabler for the rest of the benefits derived from the use of the connected and/or automated vehicle technologies. Cellular communications combined with short-range ad-hoc

[3] https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/a%20long%20term%20vision%20for%20the%20european%20automotive%20industry/race-2050-a-vision-for-the-european-automotive-industry.pdf

[4] Tractica, "Cellular V2X; 4G, 5G, C-V2X, and 802.11p Connected Vehicles: Global Market Analysis and Forecasts," 2019.

[5] https://www.lightreading.com/aiautomation/gm-commits-to-installing-atandts-5g-into-millions-of-cars/d/d-id/771607

[6] https://www.epo.org/news-events/news/2018/20181106.html

communications will allow the Mobile Network Operators to extend their LTE and mainly 5G networks (for delay sensitive and data throughput demanding services) with C-ITS services providing connectivity to the vehicles and exchanging information.

Specifically, ICT4CART with the introduction of an ICT infrastructure architecture for connected and automated traffic, which was designed, implemented, and validated in real operational environments, is anticipated to have a high industrial impact in different domains. Establishing an ICT architecture for the needs of L3 & L4 automated vehicles, towards connected integrated road transport solutions will create a leap in the European competitiveness of the transport industry, while new market opportunities will soon arise for a wide set of stakeholders. Some indicative examples include (more details can be found in the PU deliverable D9.10 “Business models”):

- A hybrid communication component based on both cellular (LTE/5G) and ad-hoc networks (ETSI ITS G5) to increase resilience, redundancy, and reliability. The growth of this market as described above, indicates the potential impact of ICT4CART hybrid connectivity developments.
- The ICT4CART flexible network architecture, based on network slicing, will allow for a certain specialisation and isolation for different types of applications with different performance requirements, deploying different types of computing e.g., cloud and edge.
- Cyber-security and data privacy mechanisms as cross-cutting concerns that were addressed in all layers of the ICT infrastructure. This could be the basis for other companies, especially SMEs, to work further in this area.
- New types of companies and business schemes between traditionally distinctive industries i.e., IT, telecom and automotive, opening up innovative market opportunities.

4.2 Societal benefits

Automotive industry has a huge challenge in reducing the environmental impact of the road transport. Together with electric driving, ITS/CCAM is tomorrow’s subject matter. Therefore, ITS/CCAM will play an important role towards decarbonisation and sustainability of road transport. Advances in ITS/CCAM services have a direct positive impact on CO_2 emissions and other environmental impacts through better use of infrastructure and more efficient driving. The implicit societal benefits foreseen/achieved through the ICT4CART UCs and technology advancements on the safety, environment and economy can be categorized as follows:

- By providing real-time notifications about emergency cases on the road (e.g., a VRU crossing a road or traffic jam notifications, etc.) sharing and synchronizing manoeuvres, ICT4CART provide increased safety.
- Sharing information about emergency incidents such as accidents or traffic jams that require immediate access by public authorities will improve the effectiveness of emergency services such as medical assistance, disaster recovery and safety services especially in high risk areas like highway tunnels or cross-border setups.
- ICT4CART solutions will/can improve traffic flow by providing real-time traffic data to the connected and/or automated vehicles. This information will enable vehicles to use alternative paths based on accurate data, thus increasing road utilization.
- ICT4CART solutions can lead to emissions reduction by shortening the time-to-destination for each driver. An accurate and real-time traffic information system is expected to increase road utilization, leading to a similar reduction in estimated time-to-destination by reducing also the unnecessary stopping/hard breaking or reduction of speed at road junctions.
- ICT4CART can increase the VRU detection rate and will minimize potential hazardous cases (e.g., in a busy crossroad or a blind turn, etc.).

Due to the COVID pandemic the ICT4CART consortium did not have the opportunity to perform extensive demonstration events and measure the actual societal benefits of the project’s Use Cases.

A glimpse of them is included in Section 6 of this report and in the PU deliverable D8.3, where the final technical evaluations are reported.

5 Exploitation and extensibility of ICT4CART results

The ICT4CART consortium aims to exploit and utilize the results of ICT4CART in several ways. Briefly, the project's outcomes are expected to be used in further research activities related or not with the project's covered areas, in the creation, development and marketing of products or services deriving from the activities performed, in the form of patents, spin-offs, societal activities, and policy changes, and on standardisation activities.

In particular, the project partners may reuse and exploit the results within their organizations, or act as facilitators in the exploitation process performed by third parties, e.g., through making results available under licenses. The exploitable results and their impact on societal challenges are considered great value, covering commercial, societal, political aspects or raising public awareness and action.

Research and academic partners mostly aim to use the project's results to enrich expertise, strengthen their collaboration networks, identify new research directions and participate in further funded research and commercial projects with industrial partners (including SMEs) to deliver research results on the leading edge of knowledge and technology. Additionally, commercialization opportunities are going to be examined and possibilities of spin-offs in the technical field of automated driving will be pursued even after the end of the project.

Commercial technology partners aim to expand their market and business horizons with an increasingly diverse mix of technologies, to create efficient, smart, and agile networks, and enable new types of connected services, automated, secured, and managed through the Cloud and Edge Computing, and provide solutions in both Infrastructure as a Service (IaaS) and housing. The project outcomes and the ambitions mentioned can serve as inputs for strategic decisions.

Road operators aim to raise awareness towards the state of the art solutions and the importance of the upgrading the existing infrastructure with the new V2X technologies within their community.

Vehicle manufactures will capitalize of the gained experience and expertise for the creation of better upgraded services for their customers, by also investigating interconnections with the traffic management market players. They anticipate that the outcomes of ICT4CART will help enhance cooperation within the business community with other strategic partners in the field of mobility services, communications, and cyber-security.

Several steps have been already made towards all directions mentioned. A detailed description per partner on the exploitation and extensibility of the project results combined with the steps towards this direction is reported in the scope of the PU-access deliverable "D9.9 Exploitation Plans (Version II)".

6 User acceptance

This section aims to depict the results of the testing execution phase of the project performed by the consortium partners on each test site. In this context, several participants were invited to examine and test the innovative solutions proposed by ICT4CART. Unfortunately, due to the COVID pandemic, the consortium had to cancel all planned large scale and open to the public demonstration events. As such only a few participants that were members of the ICT4CART consortium had the chance to participate in the evaluation events and provide their significant but rather limited to what expected feedback.

ICCS prepared a detailed questionnaire (see Annex Section 8.1) to be filled by the participants in each test site. Although the COVID pandemic did not allow for many participations on the testing activities, the consortium managed to gather several opinions on the ICT4CART proposed solutions per use case. The results of these surveys were studied carefully, and the relative conclusions are briefly presented below.

The questionnaire was structured in a way to study the impact of the solutions and tackle specifically the user acceptance matters of them in five different axes. The first set of questions targeted to study the users' status in several areas of the project's interest. Follow-up the questionnaire aimed to extract the perception of the users towards the project's goals. The third set of questions was meant to study how users would value the project's extensibility based on their personal experience, after the testing. The fourth set of questions was use case specific and was selected to extract the added value of each use case testing. The final set of questions was specifically around user acceptance matters.

General Questions

Starting with the general matters, the vast majority of participants were male, 25-34 years old, with some being also on the age group of 35-65 as well and of higher education level (bachelor's to doctoral's). None of the participants was a professional driver. Only a few were not completely possessing a car, while the rest either owned or financed/rented one. All participants possessed a driving license which either allowed them to drive motorcycles or cars, with a few being able to drive larger cargo vehicles as well. Most of the participants declared that they drive more than 5000km/year. The previous results suggest that the level of familiarity around traditional driving on the participants' sample is satisfying enough. Almost 67% of the participants have been involved in an accident as either a driver, or a passenger, or even both. All participants demonstrated a satisfying level of familiarity around the information and communications technology infrastructure within ICT4CART with the majority being completely familiar. Similar were the results around the level of awareness on Cooperative Connected and Automated Mobility systems where none of the participants declared complete non-awareness.

Perception of KPIs level

More than 70% of participants characterized the system's communication reliability as perceived from the driver's position on vehicle's actions to be good, while the rest expressed a more neutral position. 70% of the participants also experienced disruptions in the communication between the vehicle and the infrastructure on their test ride, of which the vast majority responded that the recovery time interval from this disruption was either short enough or at the right time. Almost 5% responded that the recovery took long to occur which would be the case for a statistical error or due to a random event not previously foreseen.

The vast majority of participants expressed that are/feel comfortable with traditional driving, without ADAS, infrastructure support or any other assistance but also noted that they feel comfortable enough with the combination of ICT4CART infrastructure support rather than relying on vehicle sensors alone.

None of the participants felt disturbed by the number of messages received when they were asked to take control of the vehicle unexpectedly due to a safety issue monitored by the system. In this particular case, regarding the time between the handover request and the real incident while relying on vehicle sensors alone, more than 65% said that it was adequate while the rest opposed to this view. In the same case, when ICT4CART solutions where involved, all of the participants declared that the time was adequate.

Given a certain car velocity, weather conditions, comfort aspects and safety requirements, 2/3 of the participants responded that a lane merging manoeuvre (from initiation to completion) does not feel safer in traditional driving than with the ICT4CART infrastructure and also that the ICT4CART infrastructure performs this particular manoeuvre also faster. More than 95% of the participants found the time saving of the lane merging manoeuvre, when using the ICT4CART infrastructure, to be either negligible, obvious or beyond expectations, thus, of added value to the service, while the rest mentioned that the manoeuvre was completed faster in traditional driving, which would also be again a case of a statistical error or due to a random event not previously foreseen.

Extensibility

In general, users found easy to familiarize with the HMI/ICT Messages, and all participants responded that it took them either the expected amount or very little effort towards this. However, although the majority (over 60%) believe that they were given the right information by the system to make their experience smooth and hassle-free, the rest 40% either do not express an opinion, or believe that they needed further introductory efforts.

All the participants responded positively when asked if after experiencing the ICT4CART solution, they have more trust in cooperative connected and automated driving than before. Same behaviour was demonstrated regarding the effects of the ICT4CART solution on improving the safety security perception inside a cooperative connected and automated vehicle.

The vast majority of the participants sees an added value on the proposed ICT4CART solutions with less than 5% being more neutral.

Almost 85% of the participants believe that either completely or to a good amount, the proposed solutions offered by the ICT4CART project meet their needs and expectations, with the rest of them finding the solutions at this stage being more neutral. However, the project's proposed solution seems to be at least satisfying enough for all, with over 90% putting the scale on 7-8/10.

80% of the participants are confident that investors will be interested to adopt and further develop the ICT4CART solution, while the rest kept a more neutral stance. Regarding the profitability of such investment for anyone interested, the results according to the survey are similar as well.

Some recommendations that have been received to improve the services of the proposed solutions include the fine-tuning of graphical design on HMI and some additional attention to information objects related to work zones in road infrastructure network with regards to the data quality and completeness of information, which is important for drivers and service people – staff of the operators.

User acceptance

Regarding the ease while driving by relying on vehicle sensors alone, almost 30% responded negatively, 20% had a neutral opinion, and the rest responded positively. However, almost 75% found that that the whole ICT4CART solution contributes to feeling at ease whilst driving with the rest remaining neutral, which proves the added value of the project's solutions.

Almost 90% feel more secure/safe inside a car while driving with the support of the ICT4CART solution, while the rest either prefer the traditional way or would rather just rely on vehicle sensors alone. Almost all participants felt comfortable with the ICT4CART solution as a driving experience and believe that indeed it offers an increased driving comfort experience, with a slight amount of less than 5% being neutral.

Based on the driving experience with the support of ICT4CART almost ¾ of the participants would be willing to pay for the overall ICT4CART solution, which proves that the project managed its goal, to develop and deliver services of value and quality on the connected and automated vehicles industry. On the negative answers regarding to payment for the ICT4CART solution, almost 50% are willing to pay for a similar solution from another provider that performs better than the ICT4CART and the rest are not willing to pay at all.

UC1: Smart Parking and IoT Environment

The "Smart Parking and IoT Environment" use case did not manage to gather many participations on the testing phase due to the COVID pandemic. However, some results were collected from the participants that managed to experience it.

All participants characterized the overall experience to be comfortable and safe enough while they mostly remained neutral in the criticality of the use case for connected and automated mobility. No disruption or network unavailability was noticed during the test trials from the participants. All participants agreed that the time for the connected and automated vehicle to identify the closest free parking space was either very swift or on the acceptable and expected level. No recommendations to the improvement of the service were noted, showing that this particular use case is designed and executed seamlessly.

All participants responded that they would use this service in a daily basis and probably multiple times per day. They also considered that the service should be paid mainly by the drivers either in a subscription basis or upfront as part of the cost of the vehicle. However, all participants would value the cost of the service to be less than 10 EUR a month.

UC2: Dynamic adaptation of vehicle automation level based on infrastructure information

The "Dynamic adaptation of vehicle automation level based on infrastructure information" use case gathered more participations on the testing phase however the absolute number was also small due to the COVID pandemic restrictions.

More than 70% characterized the overall experience to be comfortable and safe with the rest keeping a more neutral stance. More than 85% would characterize the overall handover experience to be smooth and timely with the rest being more neutral on this.

The response time for a decision before reaching a potential critical situation by the connected automated vehicle to handover the control with the use of ICT4CART compared to the on-board sensors only was characterized as much faster for the majority of the participants while the rest did not notice any difference. Most of the participants agreed that the infrastructure messages of the incident location were received by the vehicle enough time before it reached the incident location while a small percentage (less than 15%) expressed a more neutral position. 2/3 of the participants observed some kind of situation where the vehicle might not have received an incident message when an incident occurred, which is a case that needs further investigation as a follow up step. Most of the participants agreed that the vehicle refined its driving action and/or downscaled the automation level correctly when needed all the times while a small percentage (less than 15%) did not seem to have an opinion. None of the participants observed a situation where the vehicle made incorrect decisions in velocity adaptation and path selection. According to the vast majority of the participants, the time that took to the connected and automated vehicle in performing the scenario to reach the toll station and go through the intersection, was either on the acceptable and expected level or very swift with the speed being characterized as normal unanimously. In the aforementioned scenario, the connected and automated vehicle, based on infrastructure information, performed several acceleration/ deceleration events while doing the manoeuvres which made most participants feel uncomfortable. As a recommendation for the improvement of the dynamic adaptation of vehicle automation level based on infrastructure information services, it was noted that smoother application of the driving feature depending on the event type is required. This feedback has been taken into consideration for further examination.

More than 70% of the participants are willing to pay for the dynamic adaptation of vehicle automation level services that the ICT4CART infrastructure enables with the rest finding the service not no offer enough added value or benefit or believe that the payment should be included in the automated driving features package. All participants responded on a recurring basis for willingness to use the service in intervals from daily to monthly. Most of the participants would be willing to pay for the service either upfront as part of the cost of the vehicle or as part of the vehicle tax. The cost of the service according to participants should be between less than 10 to 50 EUR per month.

UC3: Intersection crossing (urban) & lane merging (highway)

The "Intersection crossing (urban) & lane merging (highway)" use case managed to gather enough participations on the testing phase with the absolute number being satisfactory given the COVID pandemic restrictions.

The time for the connected and automated vehicle to perform the merge to the lane and go through the intersection scenario was characterized as very swift or being at the acceptable and expected level by 90% of the participants. 70% of the participants stated that the speed vehicle was as expected while the rest found it as even high or low. 90% of the participants felt comfortable with the manoeuvres and the acceleration/deceleration events performed by the connected and automated vehicle to execute the scenario while 10% felt a little of discomfort, despite the fact that the overall experience was conformable enough for the whole sample of them. Once again, 90% would characterize the acceleration/deceleration events to be smooth while the rest 10% found them steep, which might be a case of unfamiliarity with the technologies. All participants, however, found the distance of the connected and automated vehicle from the first incoming vehicle to be enough or even long in some cases, rendering the use case safe enough. The intersection crossing and lane merging experience with the support of ICT4CART was considered to be very smooth for more than 90% of the participants, while the rest expressed a more neutral stance. Several issues were noted regarding the acceleration and deceleration events and also in the intersection crossing when standing still. This feedback will be taken into consideration for further investigation. All participants responded on a recurring basis for willingness to use the service in intervals from daily to monthly. Almost 50% of the users would be willing to pay for the intersection crossing & lane merging services that the ICT4CART infrastructure enables with the rest believing that the service should be paid by external parties or that it didn't create enough added value or benefit. The preferred ways of payment for this service were expressed to be as in a subscription, as part of the vehicle's tax or upfront as part of the vehicle's cost. The cost of the service according to participants should be between less than 10 (majority) to 50 EUR per month.

UC4: Cross border interoperability

Similarly, to the previous, the "Cross border interoperability" use case managed to gather enough participations on the testing phase given the COVID pandemic restrictions and the feedback received from participants can be considered valuable for the next steps.

Almost 45% of the participants characterized the overall border crossing experience to be comfortable enough, while the rest 45% remained neutral, about 10% expressed discomfort on the execution of the scenario, however, more than 75% would characterize the overall border crossing experience to be safe enough with about 10% being neutral and 10% disagreeing. Almost 30% of the participants noticed unforeseen effects when the transition to the new provider in the different country took place and more particularly, network outages in some areas and several technical issues. About 50% of the participants did not observe automation level remaining the same throughout the transition between the two countries and have experienced unexpected disruptions in the communication between the vehicle and the infrastructure while crossing the border. These topics are being investigated by the consortium partners.

About 50% of the participants found the Handover Gap (the acceptable interruption of connected-status) while switching to the new provider to be on the acceptable levels while the rest either found it long or even very short in some cases. There were two cases noted where the automation level changed by the vehicle because of an incident right after the border. Any uncomfortable experiences were most probably due to network availability which needs to be checked and improved. As a recommendation for the improvement of cross-border interoperability, the road network operators need to be supported and convinced to share traffic information and data in standard formats at the handover segments of their infrastructures which may offer additional safety and comfort for mobile travellers.

All participants responded on a recurring basis for willingness to use the service in intervals from daily to monthly. None of the participants would be willing to pay for the cross-border interoperability services because they either think that the service did not offer enough value/benefit, or someone else should pay for this. The preferred ways of payment for this service were expressed to be as in a pay-per-use basis (17%), a subscription (33%), as part of the vehicle's tax (33%) or upfront as part of the vehicle's cost (17%). The cost of the service according to participants should be between less than 10 (majority) to 50 EUR per month.

7 Conclusions

The ICT4CART Impact Assessment, described in this deliverable, addresses the impacts of the project in several different areas starting with the validation against the project objectives and the analysis of the project specific KPIs and to what extend the project managed to achieve them. Following, this report addressed the impacts beyond the project in three different axes, by describing the market related benefits, the environmental benefits, and the societal benefits of the project's proposed solutions. Another aspect that is analysed has to do with the exploitation and extensibility of the project's solutions and mentions what are the actions towards these directions. Finally, a user acceptance assessment is included which describes how users reacted with the systems within the test case scenarios that they participated.

The testing phase was heavily affected by the COVID pandemic, and therefore not many participations could be realized. However, despite this fact, the samples gathered from this process are of great value, were analysed carefully and several conclusions have been noted for further investigation.

Overall, given the situation, we can state that the innovative solutions of ICT4CART were widely accepted by the majority of the participants and the project managed to perform beyond expectations.

The deliverable will be made available through the project's website with a "public" dissemination level for any interested party to consult.

8 Annexes

8.1 ICT4CART Impact Assessment Questionnaire

Impact Assessment QUESTIONNAIRE

Grant Agreement Number: 768953
ICT4CART: ICT Infrastructure for Connected and Automated Road Transport

General Questions (please circle or put an "X" next to your choice)

1. What is your gender?
    - Male
    - Female

2. What is your age group?
    - 18-24 years
    - 25-34 years
    - 35-50 years
    - 51-65 years
    - >65 years

3. What is your education level? (select the highest one)
    - Primary education
    - Lower secondary education
    - Upper secondary education
    - Post-secondary non-tertiary education
    - Short-cycle tertiary education
    - Bachelor's or equivalent
    - Master's or equivalent
    - Doctoral or equivalent

4. Do you have a car?
    - Yes, I lease a car
    - Yes, I rent a car
    - Yes, I finance a car

- Yes, I completely own a car
- No, I don't possess a car

5. Are you a professional driver (e.g., taxi, lorry, etc.)?
   - Yes
   - No
6. My driving license allows me to drive (select all that apply):
   - Motorcycle
   - Motor vehicle
   - Large goods vehicle
   - Buses
   - Other

7. Approximately, how many kilometers do you drive per year (average)?
   - <1.000 Kms
   - 1.000-5.000 Kms
   - 5.000-1000 Kms
   - 10.000-15.000 Kms
   - 15.000-20.000 Kms
   - >20.000 Kms

8. Have you ever been involved in a (light or heavy) traffic accident? (optional)
   - Yes, as a driver
   - Yes, as a passenger
   - Yes, as driver and as passenger
   - No

9. What is your level of familiarity around the Information and communications technology infrastructure within ICT4CART (https://ict4cart.eu/)?

1 – No awareness	2	3	4	5 – Complete familiarity

10. What is your level of awareness on Cooperative Connected and Automated Mobility systems?

1 – No awareness	2	3	4	5 – Complete familiarity

KPI level as perceived

1. How comfortable did you feel with the messages received? Please rate the system's communication reliability as perceived from the driver's position on vehicle's actions[7].

1 – Totally unreliable	2	3	4	5 – Totally reliable

2. Have you experienced any disruptions in the communication between the vehicle and the infrastructure?
    - Yes
    - No

3. In case of any experienced mobility interruption (misbehavior/disruption) would you say that the recovery time interval was:
    - Short enough
    - At the right time
    - Long

4. I feel comfortable with traditional/basic, without ADAS, infrastructure support or any other assistance while driving:

1 – Totally disagree	2	3	4	5 – Totally agree

5. I feel more comfortable with ICT4CART infrastructure support rather than relying on vehicle sensors alone:

1 – Totally disagree	2	3	4	5 – Totally agree

6. During your test run you were asked to take control of the vehicle unexpectedly due to safety issue monitored by the system sometimes (either existing or falsely triggered). Did you feel disturbed by the number of messages?
    - Yes
    - Somehow
    - No

7. The time between the handover request (i.e., to take control of the vehicle) and the real incident while relying on vehicle sensors alone was adequate:
    - Yes

[7] If no messages to the driver/passenger/user are involved in the demonstrated UCs ignore this question.

- No
- Cannot answer

8. The time between the handover request (i.e., to take control of the vehicle) and the real incident by using ICT4CART solutions was adequate:
    - Yes
    - No
    - Cannot answer
9. A lane merging maneuver (from initiation to completion) **feels safer** in traditional driving than with the ICT4CART infrastructure support, given certain car velocity, weather conditions, comfort aspects and safety requirements.
    - True
    - False

10. A lane merging maneuver (from initiation to completion) **is faster** when using the ICT4CART infrastructure support given certain car velocity, weather conditions, comfort aspects and safety requirements.
    - True
    - False

11. A lane merging maneuver time saving when using the ICT4CART infrastructure support given certain car velocity, weather conditions, comfort aspects and safety requirements, was:
    - The maneuver was completed faster in traditional driving
    - Negligible
    - Obvious
    - Beyond expectations

Extensibility perception

1. How much effort did you have to put in to familiarize with the HMI/ICT Messages (if any; leave blank if no HMI/messages were involved)?
    - A lot
    - Usual amount
    - Very little

2. Do you feel you were given the right information by the system to make your experience smooth and hassle-free?
    - Yes
    - No
    - No opinion

3. After experiencing the ICT4CART solution, I have more trust in cooperative connected and automated driving than before.

1 – Totally disagree	2	3	4	5 – Totally agree

4. The ICT4CART solution makes me feel safer and more secure inside a cooperative connected and automated vehicle.

1 – Totally disagree	2	3	4	5 – Totally agree

5. I see added value in the proposed ICT4CART solutions.

1 – Totally disagree	2	3	4	5 – Totally agree

6. To what extent does the proposed solutions offered by the ICT4CART project meet your needs and expectations?
    - Completely
    - Somewhat
    - Very little
    - Does not meet the need

7. Overall, on a scale of 1 to 10, how satisfied are you with the project's proposed solution?

1 – Lowest	2	3	4	5	6	7	8	9	10 – Highest

8. I believe that investors will be interested to adopt and further develop the ICT4CART solution.

1 – Totally disagree	2	3	4	5 – Totally agree

9. I believe that investing in ICT4CART solutions will be profitable for investors.

1 – Totally disagree	2	3	4	5 – Totally agree

10. What recommendations would you offer to improve the services?

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Use Case specific questions

UC1: Smart Parking and IoT Environment

1. I would characterize the overall experience comfortable.

1 – Totally disagree	2	3	4	5 – Totally agree

2. I would characterize the overall experience safe.

1 – Totally disagree	2	3	4	5 – Totally agree

3. I consider parking services to be critical for connected and automated mobility.

1 – Totally disagree	2	3	4	5 – Totally agree

4. Did you notice any network unavailability?
    - No
    - Barely noticeable
    - Quite
    - A lot

5. I would characterize the time for the connected and automated vehicle to identify the closest free parking space to be:
    - Very swift
    - On the acceptable and expected level

- Very slow

6. What recommendations would you offer to improve the Smart Parking services?

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Paying for Services

1. About how often would you use this service?
    - Multiple times a day
    - Once a day
    - A few times a week
    - Once a week
    - Once every two or three weeks
    - Once a month
    - Less than once a month

2. Would you be willing to pay for the smart parking services that the ICT4CART infrastructure enables?
    - Yes
    - No

3. If no, why not?
    - The service did not offer enough value/benefit
    - I’m interested but someone else should pay for the service
    - Other:………………………………………………………………………………………………………
      ……
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4. If yes, how would you prefer to pay for these services?
    - Pay-per-use
    - Subscription
    - Pay upfront as part of the cost of my vehicle
    - As part of my vehicle tax

5. If yes, how much would you be willing to pay for these services? (Equivalent cost per month, regardless of payment method)
    - Less than 10 EUR a month
    - 10-50 EUR a month
    - 50-100 EUR a month
    - 100-250 EUR a month
    - More than 250 EUR a month

UC2: Dynamic adaptation of vehicle automation level based on infrastructure information

1. I would characterize the overall handover experience (i.e., to take control of the vehicle) comfortable.

1 – Totally disagree	2	3	4	5 – Totally agree

2. I would characterize the overall handover experience (i.e., to take control of the vehicle) safe.

1 – Totally disagree	2	3	4	5 – Totally agree

3. I would characterize the overall handover experience (i.e., to take control of the vehicle) smooth and timely.

1 – Totally disagree	2	3	4	5 – Totally agree

4. The response time for a decision before reaching a potential critical situation by the connected automated vehicle to handover the control with the use of ICT4CART compared to the onboard sensors inly was:
   - Much faster *(long or less long)*
   - Slightly faster
   - There was no noticeable difference
   - Slower

5. The infrastructure messages of the incident location were received by the vehicle enough time before it reached the incident location.

1 – Totally disagree	2	3	4	5 – Totally agree

6. Have you observed any situation where the vehicle might not have received an incident message when an incident occurred?
   - Yes
   - No

7. The vehicle refined its driving action and/or downscaled the automation level correctly when needed all the times.

1 – Totally disagree	2	3	4	5 – Totally agree

8. The vehicle made incorrect decisions in velocity adaptation and path selection.

1 – Totally disagree	2	3	4	5 – Totally agree

9. The time of the connected and automated vehicle to perform the demo scenario (reach the toll station/go through the intersection) was:
    - Very swift
    - On the acceptable and expected level
    - Very slow

10. The speed of the connected and automated vehicle to perform the scenario (reach the toll station/go through the intersection) was:
    - High
    - Normal
    - Low

11. The connected and automated vehicle, based on infrastructure information, performed several acceleration/deceleration events while doing the maneuvers (reach the toll station/go through the intersection). Did you feel comfortable by the number of those events?
    - Yes
    - Somehow
    - No

7. What recommendations would you offer to improve the dynamic adaptation of vehicle automation level based on infrastructure information services?

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Paying for Services

1. About how often would you use this service?
    - Multiple times a day
    - Once a day
    - A few times a week
    - Once a week

- Once every two or three weeks
- Once a month
- Less than once a month

2. Would you be willing to pay for the dynamic adaptation of vehicle automation level services that the ICT4CART infrastructure enables?
    - Yes
    - No

3. If no, why not?
    - The service did not offer enough value/benefit
    - I'm interested but someone else should pay for the service
    - Other:………
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      ……………………………………………………………………………………………

4. If yes, how would you prefer to pay for these services?
    - Pay-per-use
    - Subscription
    - Pay upfront as part of the cost of my vehicle
    - As part of my vehicle tax

5. If yes, how much would you be willing to pay for these services? (Equivalent cost per month, regardless of payment method)
    - Less than 10 EUR a month
    - 10-50 EUR a month
    - 50-100 EUR a month
    - 100-250 EUR a month
    - More than 250 EUR a month

UC3: Intersection crossing (urban) & lane merging (highway)

1. I would characterize the time for the connected and automated vehicle to perform the scenario (merge the lane/go through the intersection):
    - Very swift
    - On the acceptable and expected level
    - Very slow

2. The speed of the connected and automated vehicle to perform the scenario (merge the lane/go through the intersection) was:
    - High
    - As expected
    - Low

3. The connected and automated vehicle, based on infrastructure information, performed several acceleration/deceleration events while doing the maneuvers (merge the lane/go through the intersection). Did you feel comfortable by the number of those events?

- Yes
- Somehow
- No

4. I would characterize the acceleration/deceleration events to be:
   - Smooth
   - Steep

5. The distance of the connected and automated vehicle from the first incoming vehicle was:
   - Long
   - Normal
   - Short

6. I would characterize the intersection crossing/lane merging experience comfortable.

1 – Totally disagree	2	3	4	5 – Totally agree

7. I would characterize the intersection crossing/lane merging experience safe.

1 – Totally disagree	2	3	4	5 – Totally agree

8. I would characterize the intersection crossing/lane merging experience with the support of ICT4CART to be very smooth.

1 – Totally disagree	2	3	4	5 – Totally agree

9. What recommendations would you offer to improve the intersection crossing and lane merging services?

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Paying for Services

Answer for all SCN tests other than SCN3.4 Precise positioning in urban and highway location.

1. About how often would you use this service?

- Multiple times a day
- Once a day
- A few times a week
- Once a week
- Once every two or three weeks
- Once a month
- Less than once a month

2. Would you be willing to pay for the intersection crossing & lane merging services that the ICT4CART infrastructure enables?
    - Yes
    - No

3. If no, why not?
    - The service did not offer enough value/benefit
    - I'm interested but someone else should pay for the service
    - Other:………
    ………
    ………………………………………………………………………………………………

4. If yes, how would you prefer to pay for these services?
    - Pay-per-use
    - Subscription
    - Pay upfront as part of the cost of my vehicle
    - As part of my vehicle tax

5. If yes, how much would you be willing to pay for these services? (Equivalent cost per month, regardless of payment method)
    - Less than 10 EUR a month
    - 10-50 EUR a month
    - 50-100 EUR a month
    - 100-250 EUR a month
    - More than 250 EUR a month

UC4: Cross border interoperability

1. I would characterize the overall border crossing experience comfortable.

1 – Totally disagree	2	3	4	5 – Totally agree

2. I would characterize the overall border crossing experience safe.

1 – Totally disagree	2	3	4	5 – Totally agree

3. Have you noticed any unforeseen effects when the transition to the new provider in the different country took place?
    - Yes
    - No

4. If you did notice, can you describe these events?

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5. The automation level remained the same throughout the transition between the two countries making it smooth.
    - Yes
    - No

6. Have you experienced any unexpected disruptions in the communication between the vehicle and the infrastructure while crossing the border?
    - Yes
    - No

7. I would characterize the Handover Gap (acceptable interruption of connected-status) while switching to the new provider to be:
    - Very Long
    - Long
    - On the acceptable levels
    - Short
    - Very short

8. Has the automation level changed by the vehicle because of an incident right after the border?
    - Yes
    - No

9. What recommendations would you offer to improve the cross-border interoperability scenario?

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Paying for Services

1. About how often would you use this service?
    - Multiple times a day
    - Once a day
    - A few times a week
    - Once a week
    - Once every two or three weeks
    - Once a month
    - Less than once a month

2. Would you be willing to pay for the cross border interoperability services that the ICT4CART infrastructure enables?
    - Yes
    - No

3. If no, why not?
    - The service did not offer enough value/benefit
    - I'm interested but someone else should pay for the service
    - Other:

4. If yes, how would you prefer to pay for these services?
    - Pay-per-use
    - Subscription
    - Pay upfront as part of the cost of my vehicle
    - As part of my vehicle tax

5. If yes, how much would you be willing to pay for these services? (Equivalent cost per month, regardless of payment method)
    - Less than 10 EUR a month
    - 10-50 EUR a month
    - 50-100 EUR a month
    - 100-250 EUR a month
    - More than 250 EUR a month

User Acceptance

1. Relying on vehicle sensors alone contributes to feeling at ease whilst driving.

1-Strongly disagree	2-Disagree	3-Neutral	4-agree	5-Strongly agree

2. Relying on the whole ICT4CART solution contributes to feeling at ease whilst driving.

1-Strongly disagree	2-Disagree	3-Neutral	4-agree	5-Strongly agree

3. I feel more secure/safe inside a car while driving:
    - Traditionally
    - By relying on vehicle sensors alone
    - With the support of the ICT4CART solution

4. I feel comfortable with the ICT4CART solution as a driving experience.

1-Strongly disagree	2-Disagree	3-Neutral	4-agree	5-Strongly agree

5. The ICT4CART solution offers an increased driving comfort experience.

1-Strongly disagree	2-Disagree	3-Neutral	4-agree	5-Strongly agree

6. Would you be willing to pay for the ICT4CART solution, based on its impact on your driving experience?
    - Yes
    - No

7. If no, would you be willing to pay for the solution from another provider that performs better than the ICT4CART solution?
    - Yes
    - No